福井大学
工学部 研究報告
第47巻 第1号
1999年3月

Self-Organized Patterning in Balance of Power Games

Tadayuki UESUGI*, Kiyoshi KUDO*, Takashi MORI*,
Hidetoshi SUZUKI*, Masahiro KOANA*,
E. Ryoku NAKAMURA** and Osamu YAMAKAWA**

(Received Feb. 26, 1999)

The struggle for dominance among different species often results in artistically arranged patterns. Six, strikingly beautiful, self-organized patterns were obtained as the experimental result of playing the Japanese victory-defeat game commonly known as "scissors, stone and paper". The patterns emulate the balance of power among living things.

Key Words : Self-Organization, Organized Pattern, Cellular Automata

The Belouzov-Zhabotinsky reaction[1,2] and dictyiostelium discoideum lead to beautiful spiral patterns. These reactions reflect the balance between "ordering" and "disordering". Our simulation model reveals different, and dictinct, patterning forms which resemble collective population movements due to the balance between "grouping" and "invasion" effects. Living things often form groups to protect themselves against invaders. This natural ordering reflects the balance between "grouping" and "invasion" activities, and sometimes results in beautiful patterns.

Our primary model consists of only three species. They have cyclic victory-defeat relations based on the power relations between scissors, stone and paper. Every individual among the three species plays in the game. Our control parameter[3,4] λ is the ratio of invasion force to grouping force. The λ parameter yeields different kinds of order and self-organized patterning.

---

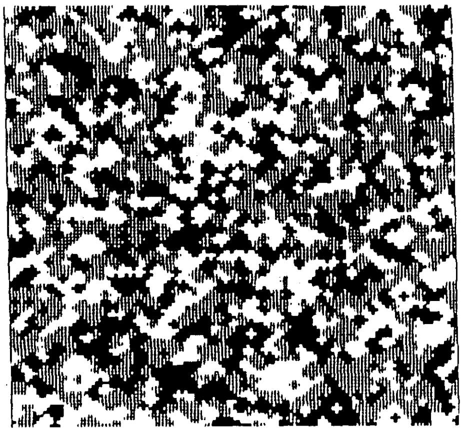
*Dept. Applied Physics **Fukui Prefectural University

At the initial state of the computerized simulation model, all individuals of species A, B and C are randomly distributed on a 128×128 lattice. In the model, each individual simultaneously plays the game of "scissors, stone and paper" with its four nearest neighbours. Points are awarded according to the following rules: one point for a draw against a member of its own species; λ points for a victory against the weaker species; and zero points for a loss against the stronger species. After playing one game, from among the four neighbours including the player, the species receiving the highest points will take over the site. This invasion is represented by colouring in the space between the players. After several hundred plays, six strikingly beautiful kinds of self-organized patterns were obtained, each according to the different value of λ represented by three monochronic tones, A (black), B (gray) and C (blank) as shown in Figure 1: **a**, $\lambda < 1$. **b**, $\lambda = 1$. **c**, $1 < \lambda < 1.5$. **d**, $1.5 \leq \lambda < 3$. **e**, $\lambda = 3$. **f**, $\lambda > 3$. By using block entropy[5] it can be readily proven that there are not any other classes of self-organized patterning. Our primary model can be modified by changing the rules of awarding points, or increasing the number of match players from four to eight, etc. and thus alter the equality between the three species.

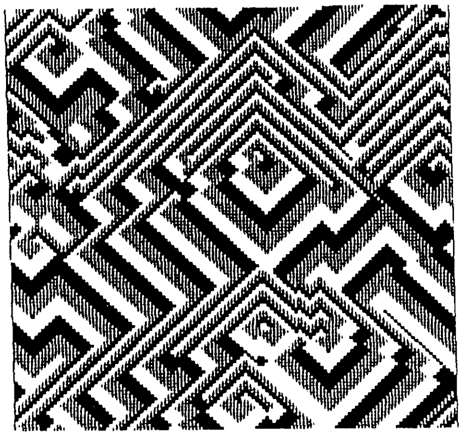
The "prisoner's dilemma game", which matches two unequal species, has also been experimeted[6]. Interesting organized patterns, similar to our **f** pattern, are available on the Internet by using David Griffeath's cyclic automata with many species[7]. Although our model is limited in deterministic processes, stochastic competition procsses, notably in region of the self-organized criticality (SOC)[8] make for interesting continued study.

references

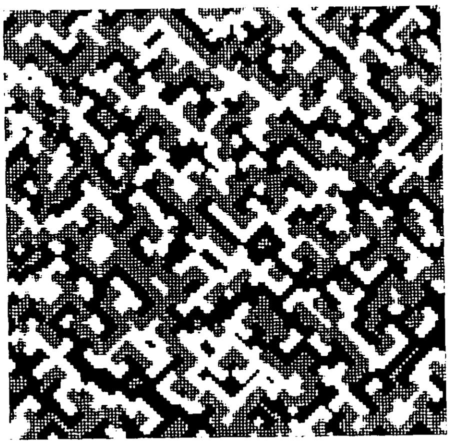
1. Belousov, B.P., Sb. ref. radats. med. Moscow (1959).
2. Zhabotinsky, A.M., Biofizika **9**, 306 (1964).
3. Shinbrot, T., Nature **389**, 574 (1997).
4. Umbanhower, P., Nature **389**, 541 (1997).
5. Grassberger, P., Int. J. Theor. Phys. **25**, 907 (1986).
6. Lloyd, A.L., Sci. American, June (1995).
7. contact to http://alife.fusebox.com/cb/alife_navframe.html
8. Johansen, A., Physica **D78**, 186 (1994); see also the review article and references therein: Clar, S., Drossel, B. and Schwabl, F., J. Phys.: Condensed Matter **8**, 6803 (1995).



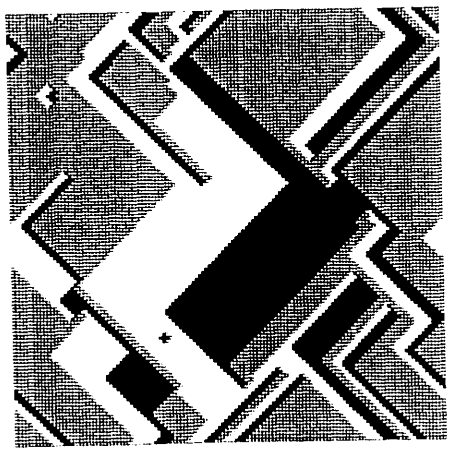
a



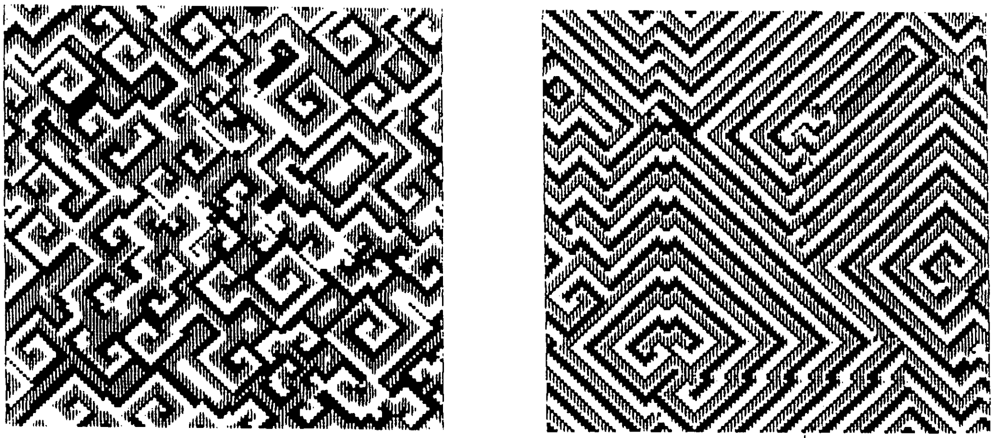
b



c



d



e f

Figure 1. Six classes of self-organized patterns. **a**, in the region of $\lambda < 1$, there appear many small colonies of species because of strong grouping effect, and they do not move moreover. **b**, on the point of $\lambda = 1$, the state changes thoroughly by the effect of equal point gettors. You can see bold large spirals moving from inside to outside. **c**, when $1 < \lambda < 1.5$, bold but small spirals are seen. **d**, in the region of $1.5 \leq \lambda < 3$, large squre block of speceis form thunder brightnings, moving to one direction. **e**, at $\lambda = 3$, many small spirals intricate with each others. **f**, we find large spirals moving from inside to outside, if $\lambda > 3$. Excepting $\lambda < 1$ case, final states behave periodically.